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(19) (CA) **APPLICATION FOR CANADIAN PATENT** (12)

(54) Method for Enhanced Oil Recovery Through a Horizontal  
Production Well in a Subsurface Formation By In-Situ  
Combustion

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Notice: This application is as filed and may therefore contain an  
incomplete specification.

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A METHOD FOR ENHANCED OIL RECOVERY THROUGH A HORIZONTAL  
PRODUCTION WELL IN A SUBSURFACE FORMATION  
BY IN-SITU COMBUSTION

ABSTRACT

5           A horizontal production well is located in the  
lower portion of a heavy viscous oil-bearing reservoir.  
A vertical injection well is located in the upper  
portion of the reservoir. Oxygen-enriched gas is  
10       injected down the injector well and ignited in the  
upper portion of the reservoir to create a combustion  
zone that reduces viscosity of oil in the reservoir as  
the combustion zone advances downwardly toward the  
horizontal production well, the reduced-viscosity oil  
15       draining into the horizontal production well under  
force of gravity.

A METHOD FOR ENHANCED OIL RECOVERY THROUGH A HORIZONTAL  
PRODUCTION WELL IN A SUBSURFACE FORMATION  
BY IN-SITU COMBUSTION

5           This invention relates to a thermal recovery  
process for recovering viscous oils from subterranean  
formations and, more particularly, to an in-situ  
combustion method for recovering such oils through  
producing wells which extend downwardly from the  
surface of the earth into the bottom of the  
10       oil-containing formation and then extend horizontally  
through the formation.

          In-situ combustion is a commonly known method for  
recovering heavy viscous oils from subterranean  
formations. In this method, an oxygen-containing gas  
15       is injected into a reservoir through an injection well  
with ignition of oil within the adjacent reservoir  
initiated by means for establishing a combustion front.  
The reservoir is usually provided with one or more  
vertical production wells for the production of oil.  
20       As the flow of oxygen-containing gas to the reservoir  
is continued, the combustion front is moved from a  
vertical injection well toward the production wells.  
The heat generated by burning reduces the viscosity of  
the oil which is displaced ahead of the combustion  
25       front toward the production wells from which the oil is  
recovered. The combustion front, in displacing the  
mobile oil, uses the residual carbonaceous deposit as  
fuel. Examples of such in-situ combustion methods are  
found in U.S. Patent Nos. 4,625,800 to Venkatesan;  
30       4,566,536 to Holmes; and 4,474,237 and 4,454,916 to  
Shu, the teachings of which are incorporated herein by  
reference.

          There are many subterranean formations containing  
heavy, i.e., viscous, oils. Such formations are known

to exist in the major tar sand deposits of Alberta, Canada, and Venezuela, with lesser deposits elsewhere, for example, in California, Utah and Texas. The API gravity of the oils in these deposits typically ranges from 10° to 6° in the Athabasca sands in Canada to even lower values in the San Miguel sands in Texas, indicating that the oil is highly viscous in nature.

Various problems are associated with the in-situ combustion drive method. There is formed in front of the combustion front and relatively near the vertical injection well, a hot bank of hydrocarbons. The viscosity of this hot bank of hydrocarbons is much less than the viscosity of the hydrocarbons existing in the remainder of the reservoir and near the vertical production well. Thus, the capacity of the reservoir to flow hydrocarbons is much less near the production well than near the injection well. This results in a condition which is sometimes referred to as "fluid blocking". When this condition occurs, flow of the lower viscosity hot bank of hydrocarbons near the injection well is retarded by the slower rate of flow of the higher viscosity hydrocarbons near the production well. Under severe conditions where highly viscous fluids are present in the reservoir, the hydrocarbons near the production well may be relatively immobile and thus may, to a large extent, prevent the hot bank of hydrocarbons from flowing toward and into the production well. This results in a loss of efficiency and an excessive amount of the hydrocarbons may be burned in the reservoir.

It is therefore an object of the present invention to provide an improved method of heavy viscous oil recovery that will overcome such a "fluid blocking" as well as other problems by providing a horizontal production well in the lower part of the reservoir and

5 establishing an in-situ combustion front in the upper  
part of the reservoir to allow gravity to assist the  
flow of the hot bank of hydrocarbons from the vertical  
injection well in the upper part of the reservoir to  
the horizontal production well in the lower part of the  
reservoir. Utilization of a horizontal production well  
will allow extended contact with the overlying  
reservoir, thereby facilitating gravity drainage and  
production of the heavy viscous oils from the overlying  
10 in-situ combustion zone.

In accordance with the present invention, there is  
provided a method for the enhanced recovery of heavy  
viscous oil from a subterranean, oil-bearing reservoir.  
At least one horizontal production well is located in a  
15 lower portion of the reservoir and at least one  
vertical injection well is located in an upper portion  
of the reservoir. Oxygen-enriched gas is injected down  
the injector well into the upper portion of the  
reservoir. Such gas is ignited in the upper portion of  
20 the reservoir to create a combustion zone that reduces  
the viscosity of oil in the reservoir as the combustion  
zone advances downwardly toward the horizontal  
production well, the reduced viscosity oil draining  
into the horizontal production well under force of  
25 gravity.

In a more specific aspect, at least one vent well  
is located in the reservoir. The oxygen concentration  
and flue gas is monitored in the horizontal production  
well. Gas injection into the upper portion of the  
30 reservoir is terminated and oxygen and flue gas is  
vented from the reservoir when a predetermined amount  
of oxygen is monitored within the horizontal production  
well. Oxygen concentration is monitored in the vent  
well. The vent well is shut in when a predetermined  
35 amount of oxygen is monitored, thereby allowing the

reservoir to consume remaining oxygen in the reservoir. The reservoir pressure is monitored. Oxygen-enriched gas is reinjected down the injection well when the monitored reservoir pressure falls below a predetermined level. The foregoing steps may be cyclically repeated.

In a further aspect, a plurality of horizontal production wells are located in spaced-apart parallel positions within the lower portion of the reservoir. A plurality of vertical injection wells are located in the upper portion of the reservoir, one such injector well being positioned intermediary of each pair of horizontal production wells. Oxygen-enriched gas is injected down each of the injection wells into the upper portion of the reservoir. The gas injected down each vertical injector well and into the upper portion of the reservoir is ignited to create a combustion zone that reduces the viscosity of oil in the reservoir as the combustion zone advances downwardly toward the plurality of horizontal production wells, such reduced viscosity oil draining into the plurality of horizontal production wells under force of gravity.

In a still further aspect, a plurality of vent wells are located in the reservoirs, a pair of such vent wells being positioned intermediary of each pair of horizontal production wells and on opposite sides of one of the intermediary injector wells.

FIG. 1 illustrates the in-situ combustion method of the present invention with a vertical injector well, a horizontal production well and a pair of vent wells.

FIG. 2 illustrates the in-situ combustion method of the present invention as being carried out with a plurality of horizontal production wells with intermediary vertical injector wells and vent wells.

FIG. 1 shows the preferred well pattern for carrying out the in-situ combustion method of the present invention for recovery of heavy viscous oils. A horizontal production well is located along the lower portion of a heavy viscous oil-containing reservoir 11. A vertical injector well 12 extends to the upper portion of the reservoir 11. A pair of vent wells 13 and 14 also extend into the upper portion of reservoir 11.

Air or oxygen is injected down the vertical injection well 12 and the upper part of the reservoir at the lower end of the injector well 12 is ignited in conventional manner, such as using standard downhole burners. An in-situ combustion zone 15 spreads over the top of the reservoir above the horizontal production well 10. The heat generated by such combustion process, where temperatures could reach 2000°F, is conducted downward, thereby reducing the viscosity of the in-situ heavy viscous oil in the reservoir 11. This in-situ combustion process takes advantage of the gravity drainage mechanism to drain the heated heavy viscous oil into the horizontal production well 10 in the lower portion of the reservoir 11.

After the combustion zone 15 has been ignited, the following process is operated in a cyclical mode. Air or oxygen is injected down injection well 12 and the reservoir 11 is pressurized up while the heavy viscous oil is produced through horizontal production well 10. Oxygen concentration and amount of flue gas in the horizontal production well is monitored and, once it exceeds a predetermined oxygen level, such as 5 Molar percent for example, the oxygen injection is terminated and the vent wells 13 and 14 are opened by suitable valves (not shown) to relieve the reservoir 11 from

these gases. This will eliminate the vapor locking of the horizontal production well 10 and also eliminate the corrosion in the tubulars. Once oxygen levels in the vent wells 13 and 14 increase, as measured by  
5 routine chromatographic techniques, to a level of 5 Molar percent for example, they are shut in and the reservoir 11 is allowed to consume the remaining oxygen. Then, when the reservoir pressure, as measured by routine methods, falls below a predetermined level,  
10 such as 25% of average reservoir pressure for example, oxygen injection through the vertical injector well 12 is resumed. This cyclical operation is continued until a 60-80% recovery of the hydrocarbons in place is realized.

15 FIG. 2 illustrates the in-situ combustion method of the present invention as being carried out with a plurality of horizontal production wells 20 spaced apart in the lower portion of the reservoir 11 and a  
20 plurality of vertical injector wells 21 and vent wells 22 spaced at intermediary positions between each of the horizontal production wells 20 so as to provide for a more effective recovery of heavy viscous oil in a reservoir.



CLAIMS:

1. A method for the enhanced recovery of a heavy viscous oil from a subterranean, oil-bearing reservoir, comprising the steps of:
  - 5 a) locating at least one horizontal production well in a lower portion of said reservoir,
  - b) locating at least one vertical injector well in an upper portion of said reservoir,
  - 10 c) locating at least one vent well in said reservoir,
  - d) injecting an oxygen-enriched gas down said injector well into the upper portion of said reservoir, and
  - 15 e) igniting said gas in the upper portion of said reservoir to create a combustion zone that reduces the viscosity of oil in said reservoir as said combustion zone advances downwardly toward said horizontal production well, said reduced viscosity oil draining into said horizontal production well under force of gravity.
  - 20 f) monitoring oxygen concentration and flue gas in said horizontal production well,
  - 25 g) terminating gas injection into the upper portion of said reservoir and venting the oxygen and flue gas from the reservoir through said vent well when a predetermined amount of oxygen is monitored in step (f) within said horizontal production well,
  - 30 h) monitoring oxygen concentration in said vent well,

- 5           i)    shutting in said vent well when a  
              predetermined amount of oxygen is monitored  
              in step (h) within said vent well, thereby  
              allowing the reservoir to consume remaining  
              oxygen in the reservoir,
- j)    monitoring reservoir pressure,
- k)    reinjecting said oxygen-enriched gas down  
              said  
              injection well when the monitored reservoir  
10           pressure falls below a predetermined level,  
              and
- l)    repeating steps (f) - (k).
2.    A method for the enhanced recovery of a heavy  
viscous oil from a subterranean, oil-bearing  
15    reservoir, comprising the steps of:
- a)    locating a plurality of horizontal production  
              wells in spaced-apart parallel positions  
              within a lower portion of said reservoir,
- b)    locating a plurality of vertical injection  
20           wells in an upper portion of said reservoir,  
              one such injector well being positioned  
              intermediary of each pair of said horizontal  
              production wells,
- c)    locating a plurality of vent wells in said  
25           reservoir, a pair of such vent wells being  
              positioned intermediary of each pair of said  
              horizontal production wells and on opposite  
              sides of one of said intermediary injection  
              wells,
- d)    injecting oxygen-enriched gas down each of  
30           said injector wells into the upper portion of  
              said reservoir, and

- 5 e) igniting said gas injected down each of said vertical injector wells and in the upper portion of said reservoir to create a combustion zone that reduces the viscosity of oil in said reservoir as said combustion zone advances downwardly toward said horizontal production wells, such reduced viscosity oil draining into said plurality of horizontal production wells under force of gravity.
- 10 f) monitoring oxygen concentration and flue gas in said plurality of horizontal production wells,
- 15 g) terminating gas injection down said plurality of injection wells into the upper portion of said reservoir and venting the oxygen and flue gas from the reservoir through said plurality of vent wells when a predetermined amount of oxygen is monitored in step (f) within said horizontal production wells,
- 20 h) monitoring oxygen concentration in said plurality of vent wells,
- 25 i) shutting in said plurality of vent wells when a predetermined amount of oxygen is monitored in step (h) with said vent wells, thereby allowing the reservoir to consume remaining oxygen in the reservoir,
- j) monitoring reservoir pressure,
- 30 k) reinjecting said oxygen-enriched gas down said plurality of injection wells when the monitored reservoir pressure falls below a predetermined level, and
- l) repeating steps (f) - (k).

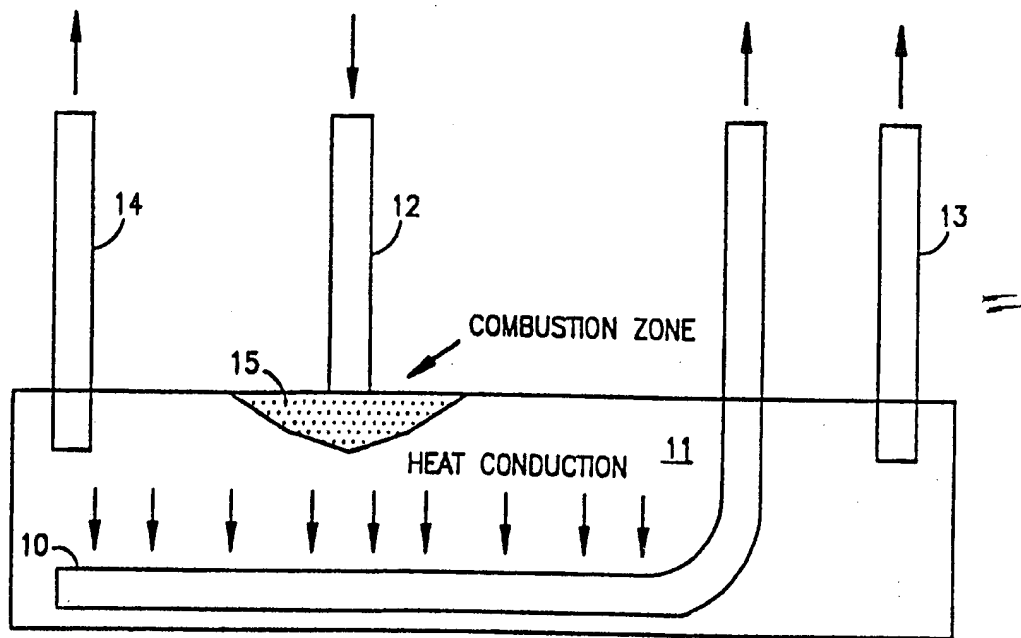


FIG. 1

Kirby, Eades, Gale,  
Baker & Potvin

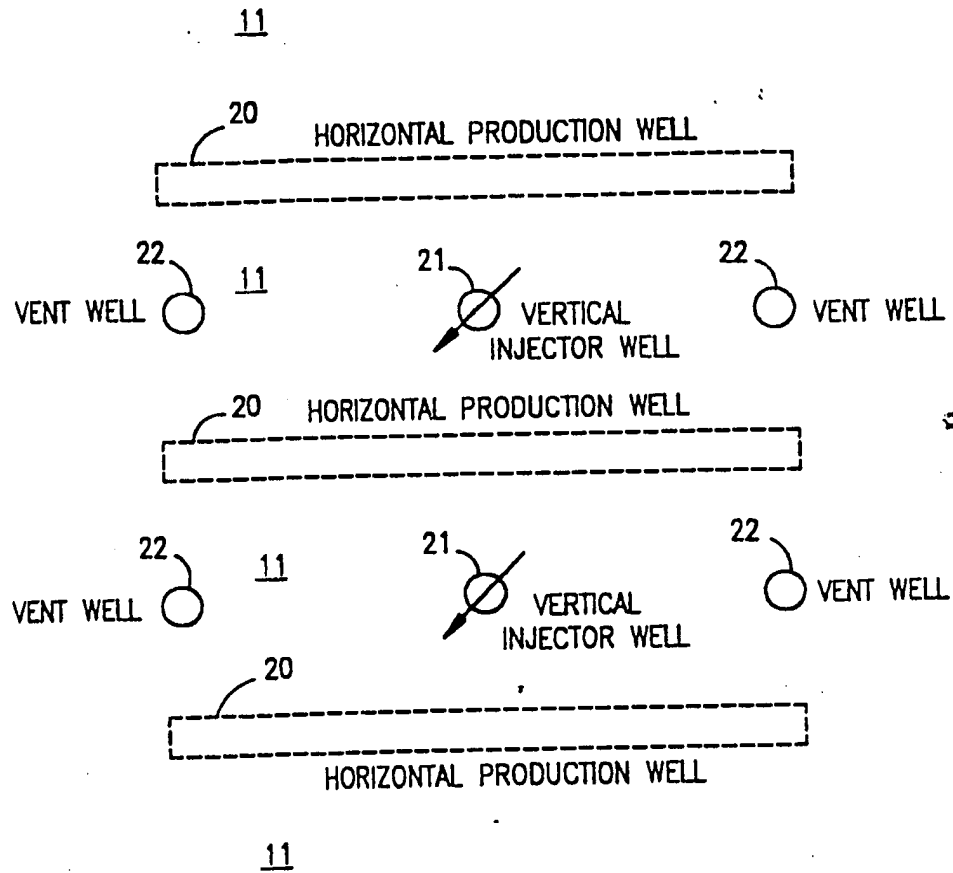


FIG. 2